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SUMMARY OF RESEARCH BY
FOREST PRODUCTS LABORATORY ON
COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES

Donald G. Coleman

Forest Products Laboratory

Wright-Patterson

JANUARY 1960

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WRIGHT AIR DEVELOPMENT DIVISION

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**SUMMARY OF RESEARCH BY
FOREST PRODUCTS LABORATORY ON
COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES**

Donald G. Coleman

Forest Products Laboratory

JANUARY 1960

Materials Laboratory
Contract No. AF 33(616)58-1
Project No. 7340

WRIGHT AIR DEVELOPMENT DIVISION
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This report was prepared by the U. S. Forest Products Laboratory under USAF Contract No. AF 33(616)58-1. This contract was initiated under Project No. 7340, "Non-Metallic and Composite Materials," Task No. 73402, "Composite Materials." It was administered under the direction of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, with Mr. W. E. Dirkes acting as project engineer.

This report covers work conducted from July 1958 to July 1959.


ABSTRACT

Developments in the program of research in composite construction for flight vehicles conducted by the U. S. Forest Products Laboratory during fiscal year 1959 are summarized. In general the approach has been to derive design criteria mathematically, and then to check by test. ~~Six~~ technical reports issued during the fiscal year are abstracted.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



W. E. DIRKES
Chief, Plastics Branch
Non-Metallic Materials Div.
Materials Laboratory

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INTRODUCTION

This annual report by the U. S. Forest Products Laboratory¹ outlines progress in research on composite constructions for flight vehicles conducted during fiscal year 1959. Information on previous work in this program was published in WADC Technical Report 52-184 and supplements 1 through 6 for fiscal years 1952 through 1958.

The research conducted this year on composite construction has been largely to determine theoretical design criteria, and to verify such criteria with experimental data. The parameters involved have in turn been evaluated by tests to determine properties of various sandwich components.

The work was divided into a number of categories, each assigned an item number.

Item 54-1. Determination of Basic Properties of Metal-Bonding Adhesives

This work includes evaluation of properties of adhesives by torsion, tension, and compression tests of end-bonded tubular specimens and application of results to stresses in lap joint specimens. In addition to previous work described in Forest Products Laboratory Report No. 1851 in 1956, the properties of Epon 422J adhesive were determined and corrections were made to the theory of Goland and Reissner for stresses in lap joints. A revision of Report No. 1851 is being made.

Item 56-4. Damping Characteristics of Sandwich Strips and Panels

An apparatus and testing procedure was developed to vibrate sandwich core specimens in shear. Measurements of forces and displacements allow determination of core elastic properties and damping capacity. The test can be run to obtain core shear fatigue characteristics. A description of apparatus and results of tests on some aluminum honeycomb cores was published in FPL Report No. 1866. Additional work on more rigid, stronger cores has shown

¹Manuscript released by author for publication as a WADC Technical Report, September 1959.

that the apparatus needed to be redesigned in order that properties could be correctly determined. Attempts to strengthen and stiffen the apparatus have been unsuccessful.

Item 56-5. Buckling of Flat Sandwich Panels Subjected to Edgewise Bending and Shear Loads

Forest Products Laboratory Report No. 1868 was published to show agreement between the theory previously developed and tests of sandwich in edgewise bending.

Item 57-1. Revision of Part I of ANC-23 Handbook

A final manuscript of the revised handbook was prepared. When this manuscript is approved by agencies of the Defense Department, it will be submitted to the Government Printing Office. Galley proofs are to be returned to the Forest Products Laboratory for final checking and the preparation of an index.

Item 57-2. Evaluation of Cores for Structural Sandwich

In this work properties of various cores are evaluated to determine standard design values. Tests were completed on aluminum honeycomb cores of 5052H39 foil, 5056 foil, and 2024-T4 foil and on a few specimens of "staggered" honeycomb. Tests were partially completed on honeycomb cores of heat-resistant plastic of glass and asbestos fibers.

Item 57-3. Design Curves for Sandwich Panels

The calculations of the design curves for sandwich cylinders subjected to external pressure have been completed and reported in Forest Products Laboratory Report No. 1869. A large-deflection analysis of the axial equilibrium loads of curved plates is being carried forward.

Item 57-4. Bending and Torsion of Sandwich Panels of Varying Thickness

Data on the torsional stiffness of a flat sandwich panel of uniform thickness are being analyzed. The torsional rigidity was found

to be less than that determined by the St. Venant theory except for long panels.

Item 57-6. Factors Contributing to Variance in Strengths of Metal-Bonding Adhesives at Elevated Temperatures

A study was started to determine the variability in the strengths at elevated temperatures of bonds made with heat-resistant adhesives to Type 301 stainless steel, and also to determine some of the principal sources of this variability. It was tentatively planned to include four adhesives, Metlbond 4021, Bloomingdale HT-424, Metlbond 302, and Epon 422, in this study, and sets of panels were prepared with the first three of these adhesives. Bonding in each instance involved 3 operators, 3 presses, and 3 bonding runs made on each of 3 days (a total of 81 panels per adhesive).

Specimens prepared with Metlbond 4021 adhesive indicated great variability and low strengths when tested at 300° F., and the results were not suitable for this study. Examination of the failed specimens showed that the emulsion cutting oil used during mill cutting of the bonded panels into specimens penetrated the bond line during the relatively short period of cutting. Some exploratory fluid immersion tests were made on different types of bonds; there was evidence that bonds to stainless steel are more affected by penetration of fluids into the bond line than are bonds to aluminum, and the penetration varies between different types of adhesives.

Specimens bonded with Bloomingdale HT-424 adhesive were also cut using the emulsion cutting oil as in the above set, but there was no evidence of fluid penetration into the bond line. Tests at 500° F. showed an overall coefficient of variation of 19.7 percent, with interaction variables between operator, press by operator, and days contributing most of this variation.

Specimens prepared with Metlbond 302 adhesive were cut using water as the lubricating fluid, and there was no evidence that the water penetrated the bond line. Tests at 500° F. showed a coefficient of variation of bond strengths of only 4.7 percent. Presses, operators, or press-by-operators interactions did not contribute any significant amount to this variability.

Item 58-1. Sandwich with Orthotropic Facings and Honeycomb Cores

Compressive buckling design curves for simply supported sandwich panels with glass-fabric-laminate facings and honeycomb cores are included in FPL Report No. 1867. Calculations for a similar report on the axial compression of sandwich cylinders are being carried forward.

Item 58-2. Study of Sandwich Panels with Dissimilar Facings

A report on the compressive buckling of flat rectangular sandwich panels having dissimilar facings has been published as FPL Report No. 1583-B (Revised). Calculations of design curves for an isotropic facing on one side and a glass-fabric-laminate facing on the other side have been started.

Item 58-3. Buckling of Sandwich Panels Supported at Edges by Beams

Work has not been started.

REPORTS ON RESEARCH IN SANDWICH CONSTRUCTION
ISSUED BY THE U. S. FOREST PRODUCTS LABORATORY,
FISCAL YEAR 1959

FPL
Report
No.

Title and Summary

- 1583-B Effects of Shear Deformation in the Core of a Flat Rec-
(Revised) tangular Sandwich Panel (Compressive Buckling of
 Sandwich Panels Having Dissimilar Facings of Unequal
 Thickness).

This major revision of a previous report considers the compressive buckling of a rectangular sandwich panel that has dissimilar facings of different thickness.

- 1865 Effect of Surface Treatment on the Adhesive Bonding
 Properties of Magnesium.

Several types of surface treatments for AZ31-H24 magnesium, including deoxidizing, chemical sealing, and anodizing methods, were investigated as pretreatments for bonding with commercial metal-bonding adhesives. In addition to original tests of bond quality, tests were also made after the specimens were aged at elevated temperature, high humidity, and salt-water spray conditions.

- 1866 An Apparatus for Measuring Internal Friction and Fatigue
 Strength of Core Materials Used in Sandwich Con-
 struction.

Apparatus and techniques are described for measuring the energy absorbed by sandwich core materials subjected to rapidly cycled shear stress. Exploratory data are given on three commercial aluminum honeycomb cores with foil thicknesses of 0.002, 0.003, and 0.004 inch.

- 1867 Compressive Buckling Curves for Simply Supported Sandwich Panels with Glass-Fabric-Laminate Facings and Honeycomb Cores.

Curves and formulas are presented for use in calculating the buckling of flat, simply supported panels of sandwich construction under edgewise compressive loads. The curves apply particularly to sandwich panels having glass-fabric-laminate facings and honeycomb cores.

- 1868 Buckling of Simply Supported Rectangular Sandwich Panels Subjected to Edgewise Bending.

The buckling of rectangular flat sandwich panels when subjected to edgewise bending was investigated experimentally. Panels of two sizes, each with thin aluminum facings bonded to an aluminum honeycomb core, were tested. Load at which buckling occurred was determined from facing load-strain data. Buckling loads were also computed theoretically. Observed buckling load was 102 percent of the theoretical value in one case and 87 percent in the other.

- 1869 Design Curves for the Buckling of Sandwich Cylinders of Finite Length Under Uniform External Lateral Pressure.

Curves and formulas for the calculation of critical external pressure are presented for sandwich cylinders of finite length. Facings of the sandwich are equal and isotropic and their individual stiffness is not taken into account. Core is isotropic or orthotropic, having natural axes in the axial, tangential, and radial directions of the cylinder. Curves are given for isotropic cores and for orthotropic cores having certain relative elastic properties. If the cores are very rigid, the method yields results that are substantially those of von Mises.

<p>Forest Products Laboratory, Madison, Wis. SUMMARY OF RESEARCH BY FPL ON COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES, by D. G. Coleman. Dec. 1959. 6p. tables (Proj. 7340; Task 73402) (WADC TR 52-184, Suppl 7) (Con- tract AF 33(616)-58-1)</p> <p>Unclassified report</p> <p>Developments in the program of research in composite construction for flight vehicles conducted by the U. S. Forest Products Lab- oratory during fiscal year 1959 are summar- ized. In general the approach has been to derive design criteria mathematically, and then to check by test. Six technical reports</p> <p>(over)</p>	<p>UNCLASSIFIED</p>	<p>Forest Products Laboratory, Madison, Wis. SUMMARY OF RESEARCH BY FPL ON COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES, by D. G. Coleman. Dec. 1959. 6p. tables (Proj. 7340; Task 73402) (WADC TR 52-184, Suppl 7) (Con- tract AF 33(616)-58-1)</p> <p>Unclassified report</p> <p>Developments in the program of research in composite construction for flight vehicles conducted by the U. S. Forest Products Lab- oratory during fiscal year 1959 are summar- ized. In general the approach has been to derive design criteria mathematically, and then to check by test. Six technical reports</p> <p>(over)</p>	<p>UNCLASSIFIED</p>
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